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**Simulation and Gaming Methods  
for Analysis of Logistics**

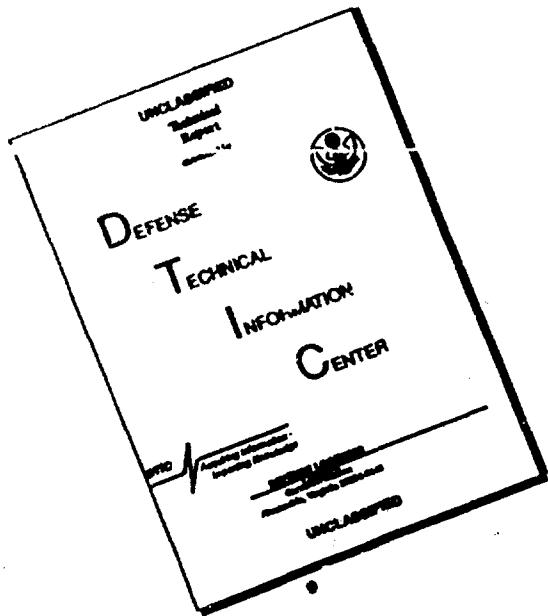


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## **Simulation and Gaming Methods for Analysis of Logistics**

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by  
Albert D. Tholen



**RESEARCH ANALYSIS CORPORATION**

MCLEAN, VIRGINIA

## FOREWORD

This paper was presented at the 1967 American meeting of The Institute of Management Sciences (TIMS) held in Boston, Mass., on 5, 6, and 7 April 1967 and is printed as a courtesy to the author. The author took part in the Military Logistics Planning Session, whose chairman was Dr. Nathan Brodsky, Director of Research and Special Projects, Office of the Assistant Secretary of Defense (Installation and Logistics). The other session participants were William A. Niskanen, Institute for Defense Analyses; John McCall, RAND Corporation; and William Brinkloe, University of Pittsburgh.

This document was based on, but was not as extensive as, an unpublished paper written jointly with Mr. Lazarus H. Todd of RAC and reviewed by the Army Staff. Several suggestions made by the Army were incorporated into the TIMS presentation. The work described was accomplished by many individuals in the Logistics Department of RAC. Special note should be made of the major contributors to the development of the Program for Overview of Logistics (PROLOG) model: Mr. Lazarus Todd, Mr. Eli P. Schneider, Mr. George Kollin, and Mr. Herman Cohen.

Lee S. Stoneback  
Head, Logistics Department

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**Simulation and Gaming Methods  
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## ABSTRACT

This paper summarizes the nature and use of a theater-level system of models (or computer programs) developed for the Army for gaming or simulating the military aspects of theater logistics. Further it describes a newly developed model that grossly approximates theater logistics.\* At present the system contains operational models for manpower, materiel, medical, transportation, maintenance, and petroleum, oils, and lubricants (POL) operations.

For purposes of military analysis and computational convenience, the theater under study is subdivided into geographic regions, and the military operation is divided into a succession of specific time periods. The system is normally applied in a series of cycles in which each model is run for all time periods, and all models are run in a sequence. The operation of the entire system through all time periods one time is called a "cycle." Each model operates through the full range of time periods to determine resource changes and logistic activity through time. The reports produced are analyzed by military-staff planners. Starting concepts, assumptions, or data are adjusted or changed and the system is run again for a second and, if necessary, a third cycle.

The system described in this paper has been programmed and utilized in a series of logistics studies and games for the Department of the Army (DA); the Office of the Secretary of Defense (OSD) (Systems Analysis); and the Special Assistant for Strategic Mobility, Joint Chiefs of Staff (JCS). It is currently serving as the basis for development of a manual Theater Logistics Model to serve as a part of the Theater Battle Model for the Joint War Games Agency (JCS).

It is useful for a wide range of applications and is a continuing effort to improve existing capabilities and develop new models.

## ABBREVIATIONS

DA	Department of the Army
DCSLOG	Deputy Chief of Staff for Logistics
JCS	Joint Chiefs of Staff
OSD	Office of the Secretary of Defense
POL	petroleum, oils, and lubricants
PROLOG	program for overview of logistics
SIGMALOG	simulation and gaming methods for analysis of logistics

\*This development is under Department of the Army Contract DA-44-188-ARO-1.

## INTRODUCTION

My subject is in keeping with the central topic of this meeting: Management Science and Long-Range Planning. Fortunately it also falls precisely under the session topic "Military Logistics Planning." Our work at RAC is in development and application of simulation and gaming methods for the analysis of logistics (SIGMALOG).<sup>1</sup> We are working closely with the Army Staff senior planner who is concerned with resource-requirement determination in planning for postulated military operations. Our focus is on total logistic requirements determination in overseas areas such as Vietnam. Our original and continuing client is the Deputy Chief of Staff for Logistics (DCSLOG), Department of the Army.

At the present time, we are also supporting the OSD and the JCS in addition to the DCSLOG. This support includes new-model development as well as operational employment of completed models. The work has several objectives but the major one to date has been to automate as much of the staff logistics planning as possible. This development has been an evolutionary activity with completion of one phase leading to another.

## SIGMALOG AS A TOOL

Emphasis to date has been on the development of a grouping of computerized models for use in simulating logistic operations in overseas theaters. (In this paper, "model" is synonymous with "computer program.") At present the system includes operational models for manpower, materiel,<sup>2</sup> medical,<sup>3</sup> transportation, maintenance,<sup>4</sup> and POL.<sup>5</sup>

For a given war plan, the use of SIGMALOG requires the assembling of senior staff planners who collectively function as a logistics command staff and simulate the logistic planning of such a staff. By use of the SIGMALOG models, they are relieved of computational and bookkeeping drudgery. The models also feed back the results (or consequences) of the planners' assumptions, factors, and decisions. With much of the work computerized, the planners can rapidly respond to changes in assumptions, factors, concepts, and policies and are thus able to examine alternatives.

The normal system inputs include a description of combat, planning data, logistics concepts and policies, detailed troop-unit data files, environmental description, and intelligence of assumed enemy action and available resources. The normal outputs are time-phased logistic tasks to be accomplished, the number of troops units required to accomplish the tasks, and the types of materiel and facilities needed for support of the war.

There are five steps in the use of SIGMALOG. Starting with a problem, the military planners develop the data required to address that problem (Step 1)

and, using standardized forms, introduce the data to the SIGMALOG models (Step 2). This information is then punched on IBM cards, and the models are run on the computer (Step 3). The reports generated are then analyzed by the planners (Step 4). The analysis may lead to rerunning the SIGMALOG models, and Steps 2, 3, and 4 are repeated until the planners are satisfied with the results. Step 5 is of course the preparation of a study report.

#### SIGMALOG Applications

The following problem areas can be addressed by use of SIGMALOG models:

- (a) Incorporate logistics into tactical and strategic games.
- (b) Develop or test logistic portions of war plans.
- (c) Evaluate competing logistic systems.
- (d) Provide a basis for establishing logistic manpower, organizational, and materiel requirements.
- (e) Examine the impact of overseas requirements on US resources.
- (f) Develop planning factors and tables for Army manuals.

For the past 3 years, SIGMALOG models have been used by RAC and the Army jointly in addressing such problems.

The common denominator of these applications is the basic SIGMALOG capability to determine requirements for logistics forces, materiel, and facilities. Forces are treated by troop units, such as infantry divisions, construction battalions, truck companies, medical companies, and post office detachments. SIGMALOG identifies the logistics jobs to be done, quantifies the amount of work or service needed (such as ton-miles of supply to be moved), and then converts workloads into troop-unit requirements. Materiel is classified into up to 20 different categories, e.g., food and gasoline.

Facilities required for receipt, movement, and storage of troop units and supply are identified. At this level of detail, SIGMALOG now includes six operational models.

#### Spectrum of Detail

Figure 1 depicts the variation in detail encompassed by the research effort. The left side of the spectrum suggests a very gross approach that would state results as thousands of men in the war (i.e., 400,000\* Army personnel in Vietnam) by location (i.e., of the 400,000, 52,000 are in Province 1; 138,000 in Province 3, etc.) and activity (i.e., of the 138,000 in Province 3, 58,000 are in combat, 40,000 are security forces, and 40,000 are logistics forces).

On the right side of the spectrum, the models deal not with populations or even troop units but with small occupational groups such as carpenters, machine operators, and stock clerks. The basic SIGMALOG models fall midway on the spectrum.

#### PROLOG

A recent development of the SIGMALOG project is a set of computer programs—program for overview of logistics (PROLOG)—that fall toward the left of the spectrum shown in Fig. 1. Use of the basic SIGMALOG models involves

\*Numbers cited are completely fictional.

a deliberate examination of the combat activity as a generator of logistic support requirements. Such an examination requires a rather precise combat scenario and a well-developed body of logistic guidance in the form of assumptions, concepts, doctrine, and factors. Full use of the models involves the provision of input data that reflect the specific scenario being addressed.

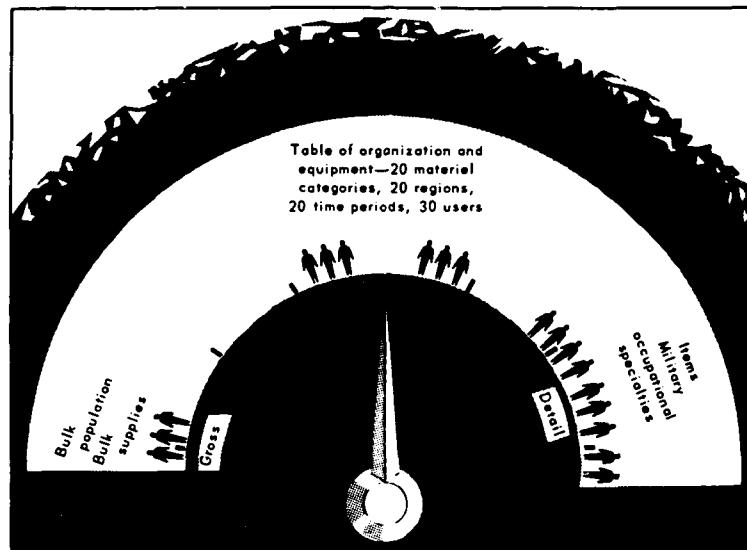


Fig. 1—SIGMALOG Spectrum of Detail

PROLOG deals with forces and materiel on quite a different and more aggregated basis than the previously mentioned SIGMALOG models. It operates on the assumption that total forces in a theater are proportional to the major combat units, geographic area, type of combat, and logistic concept and policies. To amplify that assumption, PROLOG employs prestructured tables that automatically proportion the combat-support and service-support forces to the combat units being supported. These forces are carried as "numbers of men" whereas SIGMALOG identifies forces by individual units. PROLOG reports the total population in division, corps, army, advanced logistics, and base logistics areas. This report in turn provides inputs to the routines that determine resupply requirements and tests the representative highway, rail, and air networks. PROLOG provides a means for rapidly identifying force, supply, and movement bounds for a given postulated combat plan. It does not examine the logistics tasks in detail nor can it be used to structure or tailor forces since it begins with preestablished structuring relations.

The model consists of three computer programs:

- (a) Population
- (b) Materiel
- (c) Transportation

### PROLOG Products

Use of these programs provides a means for quickly translating the tactical- and logistic-support concept and policies into the following time-phased geographically oriented reports:

- (a) Combat, combat-support, and service-support troop populations.
- (b) Supply consumption and stocks.
- (c) Shipments of forces and materiel into the theater by air and surface means and capability of the area to accommodate the shipments.
- (d) Transport requirements within the theater and capability of the various modes of transport to meet the requirements.

These reports are further explained later.

The following sections convey the basic concept of PROLOG.

Concept 1: Initial Stage. Figure 2 schematically postulates the early-deployment phase of forces to an oversea area in response to an enemy threat. At the left side of Fig. 2, the arrival of a division force is depicted. PROLOG is structured so that one can treat the buildup of a force in an oversea theater from initiation and trace its maturing through the deployment of additional combat forces and supporting forces. In Fig. 2 the force represented would be the combat division plus logistics forces needed to accomplish the receipt and initial support of the division at or near the port of entry.

Concept 2: Buildup Stage. Figure 3 illustrates the buildup phase; the division has moved out of the port area and is moving toward the country boundary. As this movement is occurring, a base section is developing to provide storage and personnel-handling facilities and perform other logistic activities. Also suggested is the fact that the first elements of an in-theater line of communications are required to move the supplies and forces from the base area to the division.

Concept 3: Mature Stage. As shown in Fig. 4, several weeks of calendar time have passed and three divisions are now deployed in the theater. The double arrows on the right indicate that the enemy threat has in fact turned into an overt attack. With several divisions now deployed along the boundary line, the commander is faced with the need to interject an intermediate support area. A corps is positioned between the base area and the divisions. If the distance from the divisions to the base were greater (e.g., if the divisions were on the offensive and moved across the border toward the right), additional intermediate areas would have to be established in order to maintain the necessary support. PROLOG also addresses the activities of the forces within each of the complexes. Figure 4 indicates that the three divisions are in contact with the enemy force and that they are engaged in combat. This fact will cause the PROLOG model to generate demands of materiel and personnel as a function of the combat or supporting roles being carried on in the various complexes.

PROLOG is therefore designed to reflect the activities that are a function of the major combat units and their type of combat, the geographic area in which this combat is taking place, and the specific logistic concepts and policies to be employed.

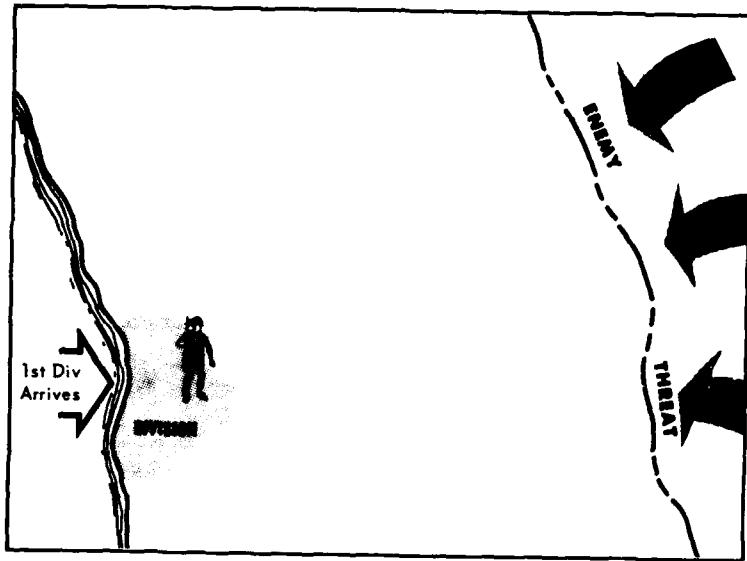


Fig. 2—PROLOG Concept 1: Initial Stage

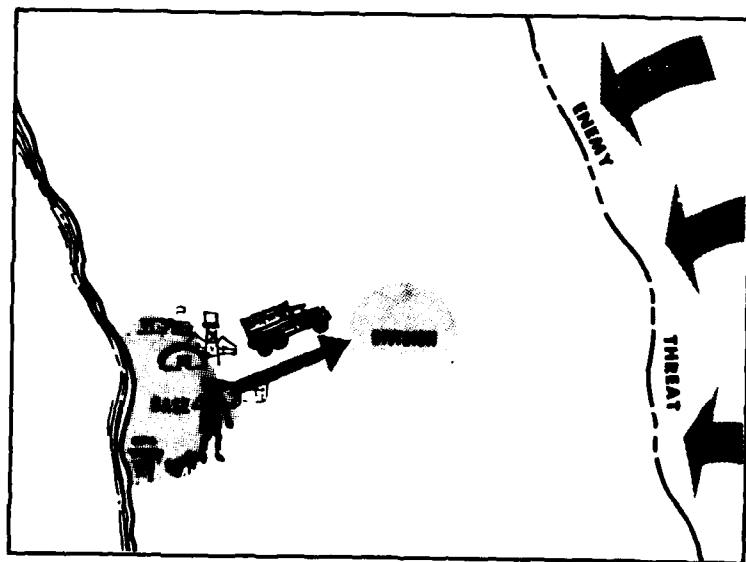


Fig. 3—PROLOG Concept 2: Buildup Stage

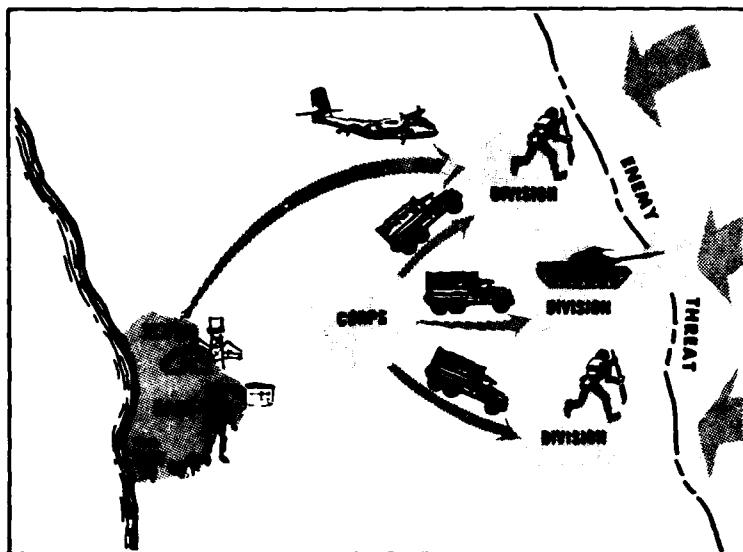


Fig. 4—PROLOG Concept 3: Mature Stage

#### PROLOG Data Requirements

All the data necessary to operate PROLOG for a given case are entered in prescribed formats that can be completed within a few hours after the war plan is understood. Keypunching can be completed in less than a day, and the results of the computer run made available to the planners within 3 days from the outset of the problem. PROLOG is run on the IBM 7044 at RAC; a typical running time for a case is 10 to 15 min. Tables 1, 2, and 3 show the type of data that must be provided to the PROLOG model.

Deployment. Users of PROLOG would have to enter the time-phased arrivals of combat units into the theater. Table 1 shows that two infantry divisions were in the theater at the beginning of the exercise, two additional units arrived in Time Period 1, two more in Time Period 2, and one in Time Period 3. In addition, one airmobile division arrived in the second time period.

Stock Distribution. Table 2 illustrates the means by which logistic policy is introduced into the PROLOG model. The division maintains 3 days' stock on hand in the division area. The next 4 days' stock is maintained in the corps area for the division, the next 8 days' in the Army rear area for the division, and 20 days' in the base area for the division. This particular policy shown adds up to a stockage in the theater of 45 days of supplies.

Consumption Factors. PROLOG determines materiel consumption on the basis of the type of force and its activity. Amounts in pounds-per-man-per-day are applied to the force size in a given region, performing a given activity, to determine the total supplies consumed by various supply categories. Additionally, the model determines supplies to be stocked to maintain stockage objectives.

As shown in Table 3, the problem involves the identification of 11 supply categories. For example, Categories 1 and 2 are kinds of food; Category 1 is perishable food that requires refrigeration and Category 2 is all other food.

TABLE 1  
Test Case: Incremental Deployments  
(Time = phased arrivals)

Type of division	Start	Time period, months			
		1	2	3	4
Infantry	2	2	2	1	—
Airmobile	—	—	1	—	—

TABLE 2  
Test Case: Stock Distribution

Type of force	Days of supply by area				
	Division	Corps	Army rear	Advance base	Base
Division	3	4	8	10	20
Corps	—	7	8	10	20
Army rear	—	—	15	10	20
Advance base	—	—	—	25	20
Base	—	—	—	—	45

TABLE 3  
Test Case: Consumption Factors  
(Pounds per man per day)

Type of force	Supply category										
	1	2	3	4	5	6	7	8	9	10	11
Division	1.0	5.0	1.4	2.6	4.2	0.8	—	1.0	1.8	63.5	9.4
Corps	1.0	5.5	0.3	8.3	24.6	4.4	—	2.5	1.9	3.9	0.6
Army rear	1.0	5.5	0.3	8.3	24.6	4.4	—	2.5	1.9	3.9	0.6
Base	1.3	7.5	4.8	4.8	34.8	6.2	—	13.0	6.8	0.8	0.1

The assumed rate of food consumption for the theater forces in a division area, expressed in pounds-per-man-per-day, is for perishables, 1 lb/man/day; and for nonperishables, 5 lb/man/day. Under Category 10, ammunition, note the great spread in rates of consumption between the division forces (the combat forces using much ammunition) and the base area (where essentially ammunition is required only for training or security actions).

### **PROLOG Results**

After the planners have identified time-phased combat forces either in, or being introduced into, the theater and have identified the activities of these forces in terms of combat level, the general war plan is depicted. PROLOG then inserts all the supporting forces as a function of these combat forces, their activities, and the level of development of the theater. Automatically, the requirement for resupply stockage, routes, and the distribution of materiel and personnel in the theater are computed. All logistic operations addressed in the model follow the prescribed rules of logistic organization and policies including such things as stock levels, their distribution, and the assumed rates of consumption by the forces in the theater. The model can treat Air Force deployment and support in much the same way as those of the Army. Figures 5 and 6 show the results obtained from the use of PROLOG in two cases run for the Army. The figures also compare these results with manually developed time-phased requirements provided to the study group by the Army and Air Force.

Figures 5 and 6 are derived from PROLOG summary reports. These reports are quite detailed and include the time-phased deployment of forces, tracing their movements and activities through time. All combat forces are identified by type (i.e., infantry division) as well as strength. The model reports out the total military strength in each of the geographical areas into which the theater has been divided. The populations in each of these areas are shown separately for Army and Air Force.

The supply report carries a complete description of the consumption, storage, and buildup of supplies in each region in the theater for each time period and category of supply. The third major report produces the time-phased movement of supply and personnel for each of the categories being addressed in the model. In addition to these three main reports, variations and summary reports are produced.

Theater Resupply: All Forces. In Fig. 5 the solid curve is a plot of the supplies required in the theater as a function of time. This graph covers 180 days. The forces are being built up over the first 90 days, which requires increased tonnages in the theater. The leveling out of the PROLOG curve reflects the approaching maturity and buildup in the theater. The dashed curve represents the supply requirements developed manually; one can see that this was more or less a straight-line computation.

Theater Strength: All Forces and Army Only. Figure 6 shows the time-phased theater populations. Note that the buildup of forces leveled out about 90 days after the start of the assumed war; this force was to be maintained through 180 days. The dashed curve shows the theater forces developed manually by the Army and Air Force. There is a considerable discrepancy between the PROLOG-developed and the service-developed deployments. By 180 days, however, these discrepancies become less significant. Attempts are currently being made to reconcile the differences shown on curves of these kinds in order to develop confidence in using PROLOG rather than the time-consuming manual computations. Of course once a case is structured for PROLOG, variations and alternatives can be very rapidly run. On the other hand the manual development of this sort of data almost never permits recomputation on the basis of variations in the input data, or for several alternatives.

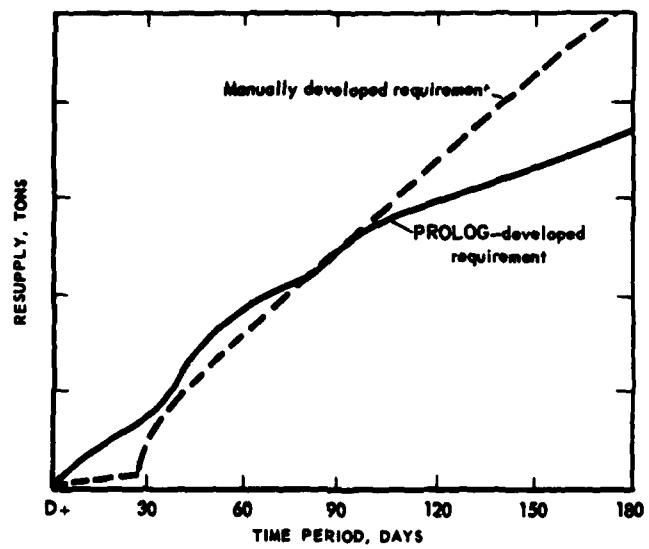


Fig. 5—Theater Resupply: All Forces

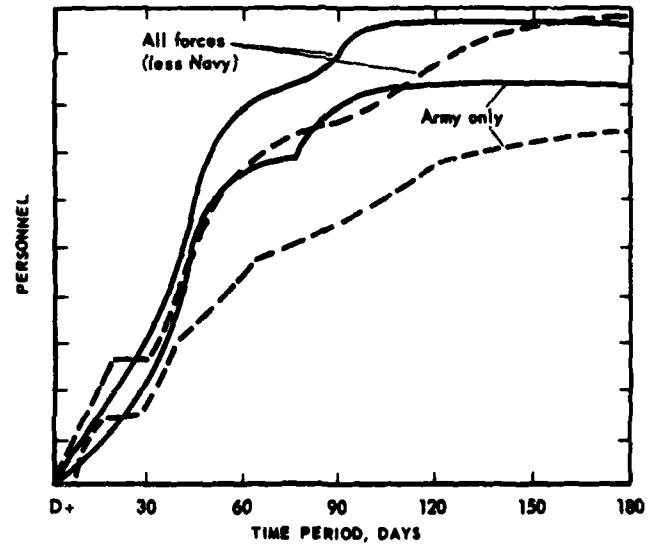


Fig. 6—Theater Strength: All Forces and Army Only

— PROLOG-developed requirement    - - - Manually developed requirement

#### CONCLUSION

The main purpose of this study group has been to develop and apply simulation and gaming methods to facilitate analysis of logistics problems. To date a basic set of such programs has been developed that will address the logistics operations in an oversea theater in considerable detail so that the information necessary to identify the time-phased forces required, the materiel needed by these forces, and the supporting facilities necessary is provided. The PROLOG model permits one to come very rapidly to grips with the logistic implications associated with postulated war plans and provides relatively meaningful results describing the time-phased forces and materiel necessary. Because of the ease of changing parameter values and the speed of the computer operation, PROLOG enables the planner both to examine variations in his support concept and assumptions and to test many alternative solutions for a given war plan.

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